FRONTIERS

Modern biotechnologies have dramatically reshaped the crop improvement research during the past decade. Biotechniques have become indispensable for efficient and effective development of new knowledge, processes, and products. IITA's biotechnology, strategized as three major themes—genomics, transgenics, and diagnostics, is directed toward the genetic improvement of staple food crops of Africa, such as cooking-banana, plantain, cassava, yam, and cowpea. This section provides some insights and progress in this program.

Leveraging "agrigenomics" for crop improvement

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Harnessing state-of-the art genomics technologies

The potential application of "Omics" technology, as demonstrated by the steadily growing impact of biosciences, in alleviating the multitude of constraints in agricultural production is rapidly becoming a reality with the advent of next-generation DNA sequencing and genotyping technologies, high throughput (HTP) metabolomics and transcriptomics, informatics, and decision-making tools. These technologies, together with rapidly evolving bio-computational tools, are accelerating the discovery of genes and closely linked molecular markers underlying important traits. This has lead to the rapid accumulation of genomic resources necessary for devising an efficient and effective breeding strategy geared toward the faster development of varieties.

The state-of-the-art technologies including the next-generation sequencing (NGS) for genome and transcriptome analysis, as well as genotyping-by-sequencing (GBS) are being adopted in R4D programs at IITA. For instance, the NGS through outsourcing and multi-partner collaboration; the RNAseq for HTP expression study in cassava; the Illumina's Golden Gate Assay for HTP single nucleotide polymorphism (SNP) genotyping in cassava, soybean, and maize as well as GBS in maize and cassava. Data generated by these techniques

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are being applied for marker-assisted recurrent selection (MARS) of drought-tolerant maize, and genome selection (GS) for high-yielding, disease-resistant cassava.

Development of an integrated molecular breeding platform

The new technologies, however, are very data-intensive and demand advanced computational and communication technologies and infrastructure for data acquisition, analysis, and management. For the effective integration of genomics technologies in our breeding schemes, we are building capacity (connectivity to the internet, the necessary hardware/software, and skilled personpower) to acquire, store, and analyze terabytes of data.

The Generation Challenge Program (GCP) of the CGIAR is developing an integrated breeding platform (IBP) to build a comprehensive and integrated crop information system enabling linkages among molecular, phenotypic, and pedigree data. The maize version of International Crop Information System (ICIS), dubbed International Maize Information System (IMIS), has been expanded to include all pedigrees of IITA maize under the Drought Tolerant Maize for Africa (DTMA) project. It has some functionality in terms of molecular data storage but this is limited and we are now generating data sets of hundreds of thousands of markers per line that require different storage solutions. The GCP is consulting with other initiatives such as iPlant and DArT and is working on collaboratively creating solutions for the needs of several user-cases including DTMA, Tropical Legumes (TL)-I, and TL-II projects. In the IBP initiative, IITA is the leading crop center to host the main web-accessible databases of cassava, cowpea, yam, and soybean. The form and functionality of the databases are still a work in progress although activities are ongoing in the application of current versions of ICIS to cassava, yam, and cowpea.

In view of the IBP initiative, we are developing a bioinformatics capacity to (a) manage the newly generated genomic resources of IITA's research crops, particularly those clonally propagated, (b) use the genomic resources in the public sector for soybean and maize, (c) use comparative genomics techniques for other African orphan crops of high importance, such as cassava, yam, and cowpea, and (d) create a bioinformatics center of excellence to train and provide access for African research scientists.

HTP by genotyping and informatics support tools

The increasing affordability of the NGS technologies has shifted critical consideration from genotyping to phenotyping. According to leading experts, it is now cheaper to genotype than to phenotype a plant. Quality phenotypic data are essential for the interpretation and use of the deluge of genomic data to identify the changes in DNA sequences that influence important traits. The fact that priority agronomic traits are complex and polygenic and interact with the environment necessitates conducting extensive and precise multi-environment evaluations of candidate breeding materials (over several years and in several locations). Therefore, there is a need to invest in precision

phenotyping of traits and data capture (from electronic sample tracking to non-invasive HTP) through the use of hand-held devices such as barcode readers and near-infrared spectroscopy. Efforts are being made to develop rapid and accurate phenotyping protocols to integrate with genomic tools in establishing breeding schemes at IITA.

A wide array of techniques and tools is being deployed to associate molecular markers with desirable phenotypic traits. Associated markers can be used to accelerate germplasm enhancement via MARS, marker-assisted backcrossing for the introgression of disease resistance and other simple traits, hence bypassing the necessity of evaluating breeding materials in the field; MARS for rapid cycle population improvement in bi-parental crosses based on genomic estimated breeding value; and GS based on a model developed with a training population to select untested samples.

Our efforts to harness the unparalleled scientific progress in the fields of genomics and bioinformatics are expected to find solutions to the recalcitrant problems confronting small-holder farmers in sub-Saharan Africa.

Researchers in IITA's Bioscience Center. Photo by L. Kumar.